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July 26, 1999

EX PARTE OR LATE FILED

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Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
The Portals
445 12th Street, S.W., TW-A325
Washington, D.C. 20554

Re: **EX PARTE**
ET Docket 95-18

Dear Ms. Salas:

ICO Services Limited ("ICO") submits for the record in the above-captioned proceeding the attached White Paper, entitled "Technical Response to Ex Parte Filing by Walt Disney Imagineering Research & Development, Inc.," prepared at the request of ICO by Sarnoff Corporation ("Sarnoff"), an engineering consulting firm.

Previously, in reply comments filed in the above-captioned proceeding on March 5, 1999, ICO urged the adoption of the Commission's proposed allocation of 85 MHz of spectrum (2025 -2110 MHz) to the Broadcast Auxiliary Service ("BAS").[1] In support of such allocation, ICO submitted technical analyses and measurements conducted by Sarnoff, which demonstrated that an allocation of 85 MHz for BAS is capable of accommodating seven analog-FM channels, – each of 12 MHz bandwidth for the vast majority of operational scenarios– "with minimal equipment impact, while maintaining the existing [ENG] service quality."[2] Furthermore, while Sarnoff's measurement data indicated some increased susceptibility to adjacent channel interference at 12 MHz channel bandwidths compared to 17 MHz, Sarnoff concluded that common operational techniques such as antenna offset pointing, cross-polarization on adjacent channels, and others --already used in the ENG service at 17 MHz--

[1] *See* Reply Comments of ICO Services Limited, ET Docket No. 95-18, at 16-19 (Mar. 5, 1999).

[2] *Id.* at App. A, p. 13.

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generally will more than offset the impact of increased adjacent channel interference measured at 12 MHz.

Subsequently, in an *ex parte* filing on April 9, 1999, Walt Disney Imagineering Research & Development, Inc. ("WDI") submitted a technical report generally confirming Sarnoff's test results. WDI, however, also focused on concerns regarding adjacent channel interference at 12 MHz channel bandwidths and raised certain issues with Sarnoff's test results.

In the attached White Paper, Sarnoff responds to the issues raised by WDI regarding Sarnoff's test results, discusses WDI's test methodology and results, and elaborates on the methods for mitigating adjacent channel interference resulting from ENG operation with 12 MHz per channel bandwidth. Specifically, Sarnoff reiterates its previous finding that, despite an inherent increased susceptibility to adjacent channel interference at 12 MHz channel bandwidths compared to 17 MHz, the effects of such interference can be mitigated with modest operational or equipment changes. Sarnoff further discusses in detail operational techniques, such as frequency coordination, spatial diversity at either the transmit or receive ends of the link, and cross-polarization of adjacent channels, which currently are available and may be readily implemented by broadcasters to mitigate adjacent channel interference at 12 MHz channel bandwidths. Consequently, Sarnoff maintains its previously stated position that "acceptable ENG [Electronic News Gathering] operation is achievable under most current operational scenarios with the 12 MHz channel bandwidth at service quality comparable to the 17 MHz channel bandwidth."

An original and one copy of this letter have been submitted to the Secretary of the Commission for inclusion in the public record, as required by Section 1.1206 (b)(2) of the Commission's Rules.

Very truly yours,

Cheryl A. Tritt
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WHITE PAPER

Technical Response to Ex Parte Filing By Walt Disney Imagineering Research & Development, Inc. Dated April 9, 1999

Report Date:
14 July 1999

Prepared For:
ICO Services Limited

Prepared By:
Sarnoff Corporation
CN 5300
Princeton, NJ 08543-5300

SARNOFF
Corporation

1. Introduction

On November 25, 1998, the FCC issued a Third Notice of Proposed Rule Making (FCC 98-309) providing proposed "Rules to Allocate Spectrum at 2 GHz for Use by the Mobile Satellite Service". A portion of this NPRM addresses reallocation of Broadcast Auxiliary Service (BAS) spectrum, proposing reduction of BAS allocation from the original 120 MHz bandwidth (1990 - 2110 MHz) to 85 MHz bandwidth (2025 - 2110 MHz), and affirming the allocation of 35 MHz bandwidth (1990 - 2025 MHz) to MSS (Earth-to-space).

The Commission had previously concluded "that retrofitting or replacement of current equipment would suffice to reduce BAS from seven channels of 17 or 18 megahertz to seven channels of 15 megahertz"[1]. In the Third NPRM, the Commission notes that "[s]tudies and information that have become available since the adoption of the *First R&O/Further Notice* indicate that it is possible to transmit FM analog BAS signals in channels as narrow as 12 megahertz and digital BAS signals in channels as narrow as 10 MHz"[2]. In proposing to reallocate this 85 MHz to BAS, the Commission invited "comment on the feasibility of the proposed BAS allocation and on any other alternate allocations or measures that would mitigate the impact to BAS of the reallocations of BAS spectrum to other services".

Reply comments by ICO Services Limited[3] incorporated technical analyses and measurements from Sarnoff Corporation (Sarnoff), which concluded that "acceptable ENG operation is achievable under most current operational scenarios with the 12 MHz channel bandwidth at service quality comparable to the 17 MHz channel bandwidth"[4]. Sarnoff found that, by using

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[1] See "Memorandum Opinion and Order and Third Notice of Proposed Rule Making and Order", FCC 98-309 at para. 31

[2] See id. at para. 32

[3] Reply comments of ICO Services Limited, Docket ET 95-18, filed March 5th, 1999

[4] See id. at Appendix A, page 1, para. 3

over-deviation at 12 MHz, link margin is not a primary limiting factor. While noting some increased susceptibility to adjacent channel interference at 12 MHz channel bandwidth compared to 17 MHz, Sarnoff concluded that common operational techniques such as antenna offset pointing, cross-polarization and others already in use at 17 MHz will generally more than offset the increased adjacent channel interference measured at 12 MHz.

Subsequently, Walt Disney Imagineering Research & Development, Inc. (WDI) submitted an Ex Parte filing on April 9, 1999, which reported on a WDI set of 12 MHz analog tests. Based on these tests, WDI validated much of the Sarnoff test data, stating that "in our tests we duplicated many of [the Sarnoff] tests [using the same equipment], yielding very similar data and confirming their results."[5] The report emphasized issues concerning adjacent channel interference, and provided test results and analysis of additional WDI tests. This WDI report generally concluded that there will be losses resulting from increased adjacent channel interference in the 12 MHz channel plan compared to the 17 MHz channelization, and then offered several suggestions on how these losses could be mitigated to achieve acceptable performance.

Specific conclusions in the WDI report state that "[w]ith rechannelization to 12 MHz spacing and no other factors altered, our tests show [adjacent channel interference is]...enough to change scenarios from 'works most of the time' to 'usually does not work'. This loss in adjacent channel interference must be mitigated somehow"[6]. Additionally, the WDI report states "[o]ur tests of second audio subcarrier response in 12 MHz channelization show unacceptable distortion due to adjacent channel interference..."[7]. But then WDI concluded "[i]n order to mitigate the losses, several suggestions may have merit"[8]. While Sarnoff agrees that there is increased susceptibility to adjacent channel interference at 12 MHz channel bandwidths compared to 17 MHz, Sarnoff

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[5] Disney Comments to 3rd Proposed Rulemaking, Docket ET 95-18, filed April 9th, 1999, page 1, para. 2

[6] See id. at page 11, para. 2

[7] See id. at page 11, para. 3

[8] See id. at page 12, para. 1

reiterates its position that the techniques suggested by WDI, as well as a variety of other techniques, are available and readily implemented to mitigate this degradation.

This report responds to issues raised by WDI concerning Sarnoff results, discusses the methodology and test results presented in the WDI report, and presents additional discussion on methods for mitigating any negative effects of the 12 MHz channel bandwidth.

2. Response to WDI Issues Concerning Sarnoff Tests

The WDI Ex Parte filing raises four issues with respect to the Sarnoff tests. In summary[9]:

1. "The Sarnoff report shows that receiver adjacent channel performance is degraded by 10dB when the channel spacing is reduced from 17 to 12.75 MHz".
2. "The Sarnoff measurements were done at 12.75 MHz channel spacing instead of the anticipated 12 MHz spacing".
3. "The Sarnoff adjacent channel tests were done at [an exceptionally high] receive level of –31dBm for the desired signal".
4. "No data on audio performance was presented by Sarnoff".

The first two of these issues relate to the impact of adjacent channel interference resulting from reduced channel bandwidth, and methods for mitigating this impact. This topic is the major focus of this paper; the specific impact of issue #2 on this discussion is negligible, as described below. The receive levels used by Sarnoff and referenced in issue #3 were specifically selected as a matter of test methodology in order to isolate test measurements from inherent receiver noise. These receive levels are not only appropriate in this context, but avoid some of the measurement errors seen when lower receive levels are used. Sarnoff did not focus on objective measurements of audio performance since our experience, validated by subjective audio tests during our reported test runs and supported by measured WDI results, is that interference impacts are seen

[9] See id. at page 2, para. 1

in the video long before they result in audio impairments. More detailed responses to these issues are provided below.

1. While there is clearly degradation in the adjacent channel interference performance of tested receivers when the channel bandwidth is reduced, Sarnoff maintains its position that acceptable operation is nonetheless achievable at the reduced channel bandwidth under most current operational conditions. The Sarnoff tests specified by WDI actually show a degradation of 8.3dB rather than 10dB at the reduced channel bandwidth. The significance of this degradation is subject to interpretation, but broadcasters are already implementing operational approaches to mitigate the effects of adjacent channel interference at 17 MHz channel bandwidths; these approaches provide mitigation well in excess of 10dB. Supporting discussion for this conclusion follows in Section 4 below.
2. As with the WDI tests, the Sarnoff tests were limited by the available equipment to channel bandwidths slightly different than those proposed in the rechannelization plan. The 12.75 MHz channel spacing was selected because it was the closest available spacing on the Nucomm equipment tested by Sarnoff. Based on analytic models validated by Sarnoff's original test results, the performance impact of an actual channel bandwidth of 12.1 MHz compared to the 12.75 MHz channel bandwidth measurements made by Sarnoff is expected to be approximately 1.25 dB. This changes the impact in the referenced adjacent channel interference test from 8.3dB to approximately 9.5dB, still better than the 10dB mentioned by WDI. This is a minor change in the overall rechannelization context, and does not affect our interpretation of the results or conclusions.
3. Sarnoff specifically selected receive levels of approximately –30dBm to –32dBm for our adjacent channel interference tests. As a matter of test methodology, Sarnoff tests were designed to isolate the influence of increased adjacent channel interference as a result of reduced channel bandwidth from other factors. Interference tests can be confounded by inherent receiver noise if the test signals approach the noise floor of the receiver. For example, in the WDI test results[10] measurable video and audio interference from noise alone is seen between –54dBm and –64dBm receive levels, which is well within the range of other

[10] See id. at page 4, Table A.II.1

test results shown[11]. Measurements below –54dBm are thus questionable in terms of quantifying adjacent channel interference separately from other factors. By using much higher receive levels, the inherent noise of the receiver is not a factor in the measurements, while the analysis of relative impacts (12 MHz channel bandwidth performance versus 17 MHz channel bandwidth) remain valid.

4. WDI has provided valuable additional data in its filing with the thorough characterization of audio performance. Sarnoff's results show that video interference is seen in all cases (both 17 MHz and 12 MHz channel bandwidths) when the desired signal level is equal or higher than the adjacent channel interferer. This result disagrees with the WDI characterization of video Just Noticeable Interference (JNI), and implies that interference with the video is generally noticeable significantly before audio interference (verified in the Sarnoff tests with subjective assessment of audio tones during the video interference measurements). Sarnoff's video interference criteria are thus more stringent than those indicated in the WDI tests.

The fact that 17 MHz channel bandwidths suffer noticeable adjacent channel interference explains the observation that current operational conditions at 17 MHz are already forcing operational solutions to address adjacent channel interference issues in crowded markets. These solutions are robust enough to resolve most interference issues likely to be seen at 12 MHz channel bandwidths.

3. Discussion of WDI Methodology and Results

WDI conducted a series of tests using substantially the same test setup as that used by Sarnoff, but with somewhat different test methodology, and reporting of test measurements focused primarily on audio distortion, with some video results also reported. The audio performance data provides valuable additional data to inform the technical discussion related to the reallocation of channel bandwidth. It is unfortunate that the specific tests performed by WDI do not generally permit direct comparison either with the Sarnoff tests, or between the 17 MHz channel

[11] See id. at, for example, page 8, Table A.III.3

bandwidth and 12 MHz channel bandwidth cases run by WDI. There are sufficient comparable cases however to provide a basis for comparison.

As mentioned above, many cases run by WDI use receive levels below where internal receiver noise effects begin to appear (between –54dBm and –64dBm[12]). These noise effects make it difficult to separate out the impacts due solely to the change in channel bandwidth. Ignoring cases below –54dBm receive level however still leaves substantial useful data in the WDI results.

Looking first at the 12 MHz channel bandwidth results in WDI Tables A.III-1 through A.III-3, it is interesting to note that the video JNI for each interferer setting occurs when the desired signal is approximately 3-4dB below the interferer level. Similarly in WDI Table A.IV.1 for 17 MHz, the first notated JNI level is also 4dB below the interferer level. There is no explanation provided by WDI when, in Tables A.IV.2 and A.IV.3 the JNI level suddenly changes to 9-11dB below the interferer.

Next, we compared the results of Table A.IV.2 to the comparable Sarnoff 17 MHz lower adjacent channel interferer test, case D2 of Table 6[13]. WDI results showed JNI with the desired signal level 11dB below the interferer level, while the Sarnoff results show JNI when the desired signal level is 7.8dB above the interferer, a discrepancy of 18.8dB. We validated this result by comparing WDI Table A.III.1 to Sarnoff Table 6, Case B2 (12 MHz). Here the discrepancy between the two results was 19.1dB.

This is a very substantial discrepancy, and indicates that Sarnoff identified impacts to the video at much lower relative adjacent channel interference signal levels than reported by WDI. Sarnoff data support the conclusion that video signals are affected by adjacent channel interference long before the audio is affected, while the WDI data seem to support the opposite conclusion. Although the source of this discrepancy cannot be determined from the available data, Sarnoff's

[12] See id. at page 4, Table A.II.1

[13] Reply comments of ICO Services Limited, Docket ET 95-18, filed March 5th, 1999, Appendix A, page 11

experience is that reliable results from JNI tests are strongly dependent on a number of factors including experienced video observers, suitable viewing conditions, high quality monitors, direct A/B comparison of distorted and non-distorted pictures, and other factors.

Extrapolating the WDI audio Total Harmonic Distortion (THD) results to the desired signal level (where Sarnoff results show JNI in the video) indicates that, at those levels, the audio distortion will be well within specification when video distortion begins to occur. This is consistent with the subjective audio tone tests used in the Sarnoff tests.

4. Mitigation Factors For 12 MHz Channel Bandwidth

In spite of test result discrepancies, both Sarnoff and WDI agree that there is increased susceptibility to adjacent channel interference at 12 MHz channel bandwidth compared to 17 MHz channel bandwidth. WDI concludes that this degradation is approximately 6dB. Sarnoff reiterates its conclusion that with this level of adjacent channel interference, "acceptable ENG operation is achievable under most current operational scenarios with the 12 MHz channel bandwidth at service quality comparable to the 17 MHz channel bandwidth"[14].

It is important to keep things in perspective. In many cases, stations typically transmit on every other channel. It is only in special instances (even in the crowded markets) where all channels are utilized simultaneously. Even in Los Angeles, if stations transmit in adjacent channels, they will offset the frequency by ~ 3 MHz as a means to improve discrimination. For all of these cases, adjacent channel interference is not an issue.

For the remaining cases, the relevant question is whether it is possible to mitigate 6-10dB of degradation with one or more operational or equipment changes. A range of options is available to achieve this goal, and most of these options can be used in combination as local market conditions require. Low cost, easily implemented choices include frequency coordination between transmitters, resetting the transmitter deviation and audio subcarrier frequencies and

[14] See id. at Appendix A, page 1, para. 3

deviation, and use of receive filters tuned to the 12 MHz channel. Somewhat more involved approaches include better filters, cross-polarization, and antenna repointing/use of alternate lines of sight.

Clearly with modest equipment changes, the adjacent channel interference can be mitigated. A major supplier for this market has issued technical notes[15] that claim with 4MHz peak video deviation and two specified audio subcarrier frequencies, their radios meet their published specifications and fit within the 12 MHz channel bandwidth. While expressing some concern about the potential for degraded adjacent channel performance, the supplier offers several suggestions including reducing the video deviation, and product enhancements such as sharper filters and audio upgrades.

Sarnoff's analysis showed a peak video deviation of 2.9 MHz provides good video quality at 12 MHz channel bandwidth. In line with this manufacturers baseline of 4 MHz and suggestion for reduced video deviation, a reduction of the peak video deviation to 2.9 MHz will provide additional mitigation against adjacent channel interference.

Operational changes already used in some markets for 17 MHz operation also provide significant mitigation of adjacent channel interference at 12 MHz. These operational changes include frequency coordination, spatial diversity at either the transmit or receive ends of the link, cross-polarization of adjacent channels, and others.

Spatial diversity of transmitters can provide adjacent channel rejection by virtue of the receive antenna pattern (i.e., 20dB null or low side lobes in the receive antenna reducing the interference) and assuming co-location of the receivers. Alternately, if interfering transmit antennas are co-located but the receive sites are separated, the same amount of rejection is also achievable. Some stations employ microwave repeaters in a coverage area to extend the range, and in many instances have a choice of pointing direction that mitigates adjacent channel interference.

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[15] Microwave Radio Communications' response to the FCC's Third Notice of Proposed Rulemaking and Order – ET Docket No. 95-18, published April 6, 1999, page 3, para. 1

Use of cross-polarization is yet another approach for mitigation of adjacent channel interference. Cross-polarization isolation between two antennas in free space can provide 30dB rejection. In terrestrial transmission applications, the isolation between polarizations is affected by multi-path reflections as well as propagation effects from terrain and other irregularities in the propagation path. Thus, in practice, a few dB of isolation rather than 30dB (depending on the specific transmission path) can be achieved from the use of cross-polarization.

Both Sarnoff and WDI also recognize better filters as a solution for the reduced channel bandwidth. WDI mentions external RF filters already in use in many markets. These filters will provide more than adequate mitigation for adjacent channel interference, if necessary, and support adjacent channel operation at 12 MHz.

In smaller markets, or in larger markets with two or more primary receive sites, the spatial diversity and polarization can be used in conjunction with frequency coordination to eliminate adjacent channel interference. Small markets could, for example, choose to use only alternate transmit channels (i.e., channels 1,3,5,7 in the total band) to reduce adjacent channel interference to negligible levels. If the receive sites in the market are spatially separated, the interference resulting from use of the even number channels is reduced even more by the amount of spatial isolation. In fact even in larger markets, most current operations do only transmit every other channel at any given time.

Finally, the audio subcarrier frequencies and deviations can be readily optimized to improve performance. The audio channel(s) in an analog FM TV system are located so as to be within the transmitter bandwidth and the receiver bandwidth. The magnitude of the subcarrier affects the audio S/N by 20 log Δf_{sc}, while the magnitude of the modulating audio signal also affects the audio S/N by 20 log Δf_a. The requirements (RS250C) for the audio signal are:

- Frequency Response 50Hz to 15KHz, +0.5dB/ –1.5dB
- S/N greater than 66dB
- T.H.D. not to exceed 0.5% out to 30KHz.

Critical measurements of audio performance, then, require setting the sub-carrier(s) frequency, setting the amount of deviation of the main carrier by the sub-carrier(s), and setting the deviation of the sub-carrier(s) by the audio baseband signal(s). Each of these parameters can be adjusted over a wide range to increase audio performance.

As a start, the highest sub-carrier frequency should be less than ½ of the total channel bandwidth (a 12MHz system would limit the highest sub-carrier to less than 6MHz, for example). Deviation of the sub-carrier by the audio baseband signal is usually 75KHz peak and requires at least 200KHz bandwidth. To allow for peaks, a typical spacing between sub-carriers is 400-600KHz to eliminate crosstalk between sub-carriers. Also, to improve audio S/N, the sub-carrier modulation of the main carrier can be increased (2MHz peak is common for some services and lower values are also used so the video Δf can be increased).

Overall, the performance of both the audio and video signals must be optimized. For a given operating bandwidth the Δf of each the video and audio must be properly apportioned. If a sub-carrier is located too high in frequency such that it lies on the receiver filter's skirts (as is the case for the second audio subcarier in the WDI tests), distortions will occur. Although the FM-to-AM conversion caused by the filter skirts may be limited by the pre-detection limiters, the phase distortion caused by the filter's edge phase characteristic can cause distortion. Further, the video signal through similar conversion can put unwanted and detectable interference into the audio channel and vice versa. The choice of video and audio Δf and sub-carrier location and Δf is critically dependent on bandwidth determining filters. The possible combinations are endless.

There are also multi-subcarrier techniques that are sometimes used that incorporate reduced deviation on the main carrier and uses highly companded baseband audio. As many as nine lower deviation sub-carriers have been used with only modest reduction in video deviation. In summary, a large range of options for tuning the audio and video parameters to maximize performance are available; both the Sarnoff and WDI tests used conservative values for these parameters, allowing for significant improvement and reduced interference susceptibility with optimal parameter settings.

In most markets, the operational and/or equipment changes already implemented at 17 MHz channel bandwidths provide more than enough additional channel isolation to fully mitigate the 6-10dB impact of the rechannelization from 17 MHz to 12 MHz. While there may be some specific markets where mitigation approaches acceptable for 17 MHz channels are marginal for 12 MHz channels, there are clearly a wide range of relatively simple approaches for providing adjacent channel isolation that will be effective in most markets.

5. Conclusions

Both Sarnoff and WDI agree, as stated by WDI, "[w]ith rechannelization to 12 MHz spacing and no other factors altered..."[16], the receiver susceptibility to adjacent channel interference is increased. However, Sarnoff test results (validated by current operations in the field) indicate that adjacent channel interference is already an issue at 17 MHz in some markets, and in those markets other changes have already been implemented to mitigate this interference. These changes, alone or in combination to the extent necessary, are robust enough to also mitigate the additional interference resulting from the change in channel bandwidth to 12 MHz. Thus, Sarnoff stands by its conclusion, that acceptable ENG operation is achievable under most current operational scenarios with the 12 MHz channel bandwidth at service quality comparable to the 17 MHz channel bandwidth.

[16] Disney Comments to 3rd Proposed Rulemaking, Docket ET 95-18, filed April 9th, 1999, page 11, para. 2